Chapter 15
Wire and Cable

15-1. General

Wire and cable systems should be designed for long life with a minimum of service interruptions. The materials and construction described in Guide Specification CW-16120 provide construction materials consistent with these service requirements. IEEE 422 provides overall guidance in planning, designing, and installing wire and cable systems in a power plant. Topics covered in the IEEE guide include cable performance, conductor sizing, cable segregation systems, installation and handling, acceptance testing, and other related subjects. Additional guidance is provided in EPRI EL-5036, Volume 4.

15-2. Cable Size

The minimum size of conductor for current-carrying capacity should be based on the National Electrical Code (NEC) requirements for 60 °C insulated wire. NEMA WC50 and WC51 provide ampacities for high-voltage cables and for multiconductor cables not covered in the NEC. Circuit voltage drop should be checked to ensure the total drop from the source to the equipment does not exceed requirements of Articles 210 and 430 of the NEC.

15-3. Cable System Classification

All cables or conductors, except lighting system branch circuits, should be listed in the conduit and cable schedule under the appropriate heading as either power or control cable. Design of the cable systems is divided into three classifications according to functions, as follows:

a. Interior distribution.

(1) Power and lighting conductors include circuits from the station service switchgear to distribution centers or to station auxiliary equipment; branch circuits and control circuits from distribution centers to auxiliary equipment; feeders to lighting panels; and lighting branch circuits. No conductor size smaller than No. 12 AWG should be used, except for control circuits associated with heating and air-conditioning equipment where No. 14 is adequate.

(2) Multiconductor power cables should be used for the larger and more important circuits such as feeders to distribution centers in the dam, the powerhouse, and the switchyard; lighting panels; and any other major project loads. Single-conductor wires can be used for branch circuits and control circuits from distribution centers to equipment when installed in conduit. For cable tray installations, Article 318 of the National Electric Code (NFPA 70-1993) dictates the use of multi-conductor tray rated cable for all circuits requiring No. 1 cable or smaller.

b. Control and communication.

(1) Control cables include station control and annunciator circuits from the control room switchboards, unit instrument boards, exciter cubicles, and secondary control centers. Such circuits are generally identified with the DC control system, the instrument bus, or the annunciator system. All control cables, except those for the communication system and special circuits noted in paragraph 15-3*b*(6), should comply with the requirements of Guide Specification CW-16120.

(2) The cables should be adequately supported in long vertical runs and where they enter or leave the cable trays. Multi-conductor cables are usually No. 19/25 or 19/22 for control, metering, and relaying circuits and No. 16 stranded for annunciator circuits. All current transformer secondary circuits should be No. 19/22 or larger. Larger conductor sizes may be required to take care of voltage drop, or to decrease the burden on instrument transformers.

(3) No splices should be made between the terminal points of the cable.

(4) In selecting cables, consideration should be given to minimizing the number of different cable items ordered for installation or stocked for maintenance. For example, the 4-, 6-, and 8-conductor cables might be omitted and 5-, 7-, and 9-conductor cables substituted, leaving one spare conductor. The practice of including one or more spare conductors in each cable of more than four conductors is considered desirable. Selection of sizes and numbers of conductors per control cable should be limited, if possible, to combinations that have 50 ft or more in each item of a lot ordered.

(5) All wiring for the telephone system, including circuits from the main cabinet to the local telephone jacks, should be listed under “Telephone” cables in the schedule. Selection of telephone system conductors will be dictated by the application.

(6) Special circuits such as calibrated ammeter leads, and coaxial cable circuits to carrier-current capacitors, computer networks, microwave, and video, should be

scheduled under control cables or telephone cables, whichever is applicable. Clarifying remarks concerning the type of the conductor and the supplier should be included. Where fiber-optic cables are used, installation and application should follow the manufacturer's recommendations. Two-conductor No. 19/25 control cables may be used where the circuit lengths make it impractical to obtain calibrated leads with the instruments.

(7) Analog and digital signal cables. There is no standard specification for these cables. There are general guidelines that should be followed in selecting the general characteristics of the signal cable to be used. Some of these guidelines are:

(a) PVC insulation or jacketing may not be used.

(b) Insulation and jacket material should pass UL flame tests.

(c) Analog signal conductors must be paired and twisted together with a shield, signal conductor, and return conductor in the same pair.

(d) Conductor pairs should be twisted, variable lay, pairs individually shielded.

(e) Multipair cables should have an overall shield and an outer jacket.

(f) Shields should be grounded at one end only to prevent shield current.

(g) Conductor size should be not less than No. 18 AWG.

(h) Minimum insulation level should be 150 V.

c. Grounding conductors. Embedded grounding system conductors should be stranded, soft-drawn, bare copper wire following the recommendations of Chapter 13. The cables need not be scheduled, but if brought out in test stations, should be suitably tagged for future identification.

15-4. Conduit and Cable Schedules

a. General. The intent of the conduit and cable schedule is to provide all pertinent information to assist in installing, connecting, identifying, and maintaining control and power cables. When not included with the plans for construction bids, the specifications indicate cable schedules will be furnished to the contractor.

b. Power circuits.

(1) Each cable and conduit should be identified with an individual designation. The cable and conduit are tagged with a designation at each end and at intermediate points as necessary to facilitate identification. The designation is also shown on equipment wiring diagrams, tray loading diagrams, on conduit plans and details, on cabinet layouts, and on junction and pull box layouts.

(2) The scheduling of cables should always include (opposite the cable designation) the following information:

(a) Number and size of conductor.

(b) Function or equipment served.

(c) Origin and destination.

(d) Routing via conduits and trays.

(e) Special conditions.

(f) Estimated length.

(3) The scheduling of conduit should include (opposite the conduit designation) the following:

(a) Size and type of conduit.

(b) Function or equipment serviced.

(c) Origin and destination.

(d) Special conditions.

(e) Length.

(4) Conduit and cable should have the same designation if possible. The number assigned should give information about the service rendered by the cable, the termination points of the cable, and the approximate voltage or power classification.

(5) Generally, each cable between major units of equipment or from major units of equipment in the powerhouse to structures external to the powerhouse is assigned a number made up of three parts, as follows:

(a) The first part of the cable number shows the beginning of each cable run and is composed of uppercase letters and numerals assembled into a code to represent the various major units of equipment, switchgear,

switchboards, cabinets, etc., located throughout the powerhouse.

(b) The second part of the cable number is composed of a single lower-case letter and number. The letter indicates the type of service rendered by the cable, i.e., power, alarm, etc., while the number serves to differentiate between cables of a particular type running between two points.

(c) The third part of the cable number shows the termination of each cable run and is composed in the same manner as the first part of the cable number.

Example: Cable Number

Cable ID: SC-u3-G1

Breakdown: SC = Start of cable run (Main control switchboard)
u = Type of service (Annunciator lead)
3 = Number of such cable (3rd annunciator lead cable to Generator No. 1; there might be 6 or 9 cables, for example, each with its own number)
G1 = Termination of cable (Generator No. 1)

(6) Cables between low-voltage equipment (such as motor control centers) and minor units of equipment (such as station auxiliaries) have no code letter and numeral to show the termination of the cable run. The cable numbers in these cases are made of only two parts. The first part indicates the start of the cable run, while the second part indicates the type of service rendered by the cable.

Example: Cable Number

Cable ID: CQ5-c12

Breakdown: CQ5 = Start of cable run (480-V load center No. 5)
c = Type of service (Control circuit)
12 = Circuit number

(7) Numbers are assigned to the power and control cables so the power circuit of a given number is controlled by a control circuit having the same number, the differentiation being only in the code letter designation of the circuit duty. As an example, cable "CQ5-c12" would be the control for power circuit "CQ5-q12."

(8) There are cases where a circuit terminates at several duplicate devices. For instance, an annunciator circuit runs to a junction box and is spliced at this point with branches running to a thermostat in each tank of a transformer bank. In such a case, the cable from the switchboard may have a designation such as S1-u2-T1 and the branch designations are S1-u2.1-T1, S1-u2.2-T1, and S1-u2.3-T1.

(9) Spare conduits are numbered by using a three-part number where possible. In cases where the spare conduits leave a certain switchboard or distribution center and are stubbed at the end of the building, only a two-part number can be used, e.g., CQ01-s1 is a spare conduit leaving motor control center CQ01.

c. Lighting circuits.

(1) Numbering of the circuits and conduits for lighting circuits is similar to the power circuit numbering scheme. Each cable is assigned a three-part number such as SR1-r3-CR4. Full information for these conduits and circuits is given on lighting drawings. Circuits from the lighting cabinets receive numbers corresponding to the switch numbers in the lighting cabinets.

(2) The lighting drawings indicate, between each outlet, the conduit size, number of conductors, and the size of the conductors. The number of conductors is indicated by drawing small lines across the conduit, one line for each conductor. At the side of each outlet, there is a small number indicating the circuit to which the outlet is connected, another number at the side of the outlet indicating the size of the lamp to be installed if not covered elsewhere. Where the conduit leaves the first outlet to run to the lighting cabinet, the circuit numbers of the conductors in the conduit are indicated.

d. Code letter identification.

(1) General. Code letters are broken down into three classes: terminal equipment, modifying terms for terminal equipment, and cable service classification. Code letters and explanations are given in Table 15-1 below.

Table 15-1
Code Letters for Conduit and Cable

Terminal Equipment

• Operator's desk, switchboards, and switchgear

SA - Fishwater Generator Switchboard
SAT - Satellite Digital Processor
S - Generator Switchboard (Add No.)
SB - Battery Switchboard
SC - Main Control Switchboard
SCC - Main Control Console
SG - Graphic Instrument Switchboard
SL - Load Control Switchboard
SO - Station Service Switchboard
SOC - System Operations Controller
SJ - 13.8 *kV* Switchgear (Add No.)
SP - 4160 V (or 2400 V) Switchgear
SQ - 480 V Switchgear (Add No.)
SH - Heating Switchgear
ST - Status Board
SU - Motor Control Center (Add No.)
SR - Lighting Switchgear
SX - Excitation System Equipment (Add No.)
GN - Generator Neutral
OD - Operator's Desk
CC - Carrier Current Equipment
ER - Electrical Equipment Room Cabinets
MUX - Multiplexer
MW - Microwave Terminals
FSC - Fishway Switchboard
DOC - Digital Operations Controller
ROC - Remote Operations Controller
FSP - 4160 V Fishway Switchgear
FCP - 4160 V Fishway Controller
FSQ - 480 V Fishway Switchgear
FSU - Fishway Unit Switchgear
TF - Telephone Frame

• Load centers

CP - 4160 V (or 2400 V)
CQ - 480 V
CR - 120/240 V (120/208 V)
CD - 48 V DC
CE - 125 V DC
CF - 250 V DC
CA - Emergency Lighting
CH - Preferred AC
CY - (CO_2) Cabinet
DQ - 480 V (Dam)
FCP - 4160 V (or 2400 V) Fishway
FCQ - 480 V (Fishway)
PQ - 480 V (Project)

• Apparatus

A - Actuator (Governor)
B - Battery
G - Generator
GF - Fishwater Generator
X - Breaker (Add Voltage Letter)
T - Transformer (power)
Z - Disconnecting Switch (Add Voltage Letter)
CT - Current Transformer
V - Voltage Transformer
EG - Engine Generator
MG - Motor Generator
MC - Motor Control Cabinet
M - Motor
PT - Potential Transformer (Separate Apparatus modified by voltage as PTW)
K - Crane
FT - Fishway Transformer

• Miscellaneous terminal equipment, boxes, or structures. Some items in this list are used for cable and conduit terminals, but a majority are used only as modifying suffixes for devices on schematic diagrams:

AA - Governor Air Compressor
AH - Air Horn
AN - Annunciator
AQ - Governor Oil Pump
AR - Annunciator Reset
AS - Ammeter Switch
BC - Battery Charger
BG - Break Glass Station
BK - Brakes
BU - Bubbler System
BV - Bypass Valve or Butterfly Valve
CAC - Central Air Conditioner
CJB - Junction Box, Master Control Circuits (Modify by Unit No.)
CM - Channel Manometer
CPD - Capacitance Potential Device
CTC - Control Terminal Cabinet
DP - Drainage Pump
DS - Deck Station
DT - Differential Transmitter (Transducer)
DWP - Domestic Water Pump
EA - Sewage Aerator
EC - Effluent Comminutor
EF - Exhaust Fan
EH - Electric Heater
EHQ - Electric Oil Heater
EL - Elevator
EP - Sewage (Effluent) Pump
ETM - Elapsed Time Meter
EV - Electrically Operated Valve
FM - Flow Meter
FP - Fire Pump
FS - Float Switch (Device 71 preferred)
FTC - Fishway Terminal Cabinet
FW - Float Well
FWG - Forebay Water Level Gage
GH - Generator Heater
GI - Ground Insert
GP - Grease Pump
GW - Generator Cooling Water (Pump or Valve)
HC - Head Cover Sump Pump
HD - Air Conditioning Damper
HF - Air Conditioning Air Filtration Equipment

(Continued)

Table 15-1. (Concluded)

HH - Air Conditioning System Humidifier
HP - High Pressure Thrust Bearing Oil Pump
HQ - Conditioning System Oil Pump
HR - Air Conditioning System Refrigeration Pump
HV - Air Conditioning System, Master Devices
HW - Air Conditioning System Water Pump
HY - Hypochlorinator
IG - Intake Gate
IM - Intake Manometer
IS - Intruder Detector System
IQ - Intake Gate Oil Pump
IV - Inverter
JB - Junction Box
LC - Load Control Cabinet
LT - Outside Lighting (480 V)
LTH - High Bay Lighting
LTU - Line Tuning Unit
MO - Load Control Master
MOD - Motor Operated Disconnect
OR - Operations Recorder
OS - Load Control Station Operation Selector
PA - Station (Plant) Air Compressor
PB - Pull Box or Pushbutton
PC - Program Controller
PG - Penstock Gate
PH - Powerhouse (Add No.)
PR - Project Building
PS - Potential Selector or Pressure Switch (Device 63 preferred for pressure switch)
PT - Pressure Tank
PV - Penstock Valve
QPD - Oil Transfer Pump (Dirty)
QPL - Oil Transfer Pump (Lube)
QPT - Oil Transfer Pump (Transil)
RC - Code Call Relay Box
RF - Recirculating Fan
RW - Raw Water Pump
SD - Servo or Shaft Oil Catcher Drain Pump
SF - Supply Fan
SN - Stop Nut
SO - Load Control System Selector
TA - Transformer Cooling Equipment Air System
TB - Telephone Box or Test Block
TBA - Turbine Bearing Oil Pump - AC
TBD - Turbine Bearing Oil Pump - DC
TC - Terminal Cabinet
TD - Transformer Deluge
TE - Thermostat (Heating & Ventilation Equipment Drawings)
TH - Preferred AC Transformer
TM - Tailrace Manometer
TP - Turbine Pit
TQ - Transformer Cooling Equipment Oil Pump
TS - Test Station
TWG - Tailwater Level Gage
UAC - Unit Air Conditioner
ULC - Unit Load Control Selector
US - Unit Selector
UV - Unloader Valve
UW - Unwatering Pump
VQ - Valve Oil Pump
XA - Circuit Breaker Air Compressor
XF - Circuit Breaker Cooling Fan
VS - Voltmeter Switch
WG - Water Gate (Sluice, Weir, etc.)
WH - Water Heater (Hot Water Tank or Boiler)
WP - Gate Wash Pump - Deck Wash Pump
WV - Water Valve

Modifying terms for terminal equipment

• As an aid to further identification of voltage class and location of the equipment, the following letters are applied to separately mounted breakers, disconnecting switches, current transformers, and voltage transformers:

U - 500 *kV*
M - 230 *kV*
W - 115 *kV*
J - 13.8 *kV* or 7.2 *kV*
P - 4160 V (or 2400 V)
Q - 480 V
R - 120/240 V (120/208 V)
F - 250 V DC
E - 125 V DC
D - 48 V DC
H - 120 V Preferred AC

• Other modifying terms

O - (as GO, TO) - Station Service
N - (as GN1, TN1) - Neutral
Y - (as CY for CO_2 Cabinet) - CO_2

Service classification

a - Current Transformer - Shunt Leads
c - Control Circuits, (Circuit Breaker Control Circuits, Excitation System Control Circuits, and Governor Control Circuits)
d - 0 - 48 V DC
e - Power Circuit, 125 V DC
f - Power Circuit, 250 V DC
h - 120V Preferred AC
j - Power Circuit, 13.8 *kV* AC
m - Power Circuit, 230 *kV* AC
p - Power Circuit, 4160 V or 2400 V AC
q - Power Circuit 480 V AC
r - Power Circuit (Lighting) 120/240 V or 120/208 V AC
s - Spare Conduit
tr - Radio Circuits
t - Telephone Circuits, Intercommunication Circuits
ts - Sound Power Circuit
u - Alarm Circuits; Annunciator Circuits; Water Flow Level; Pressure; and Temperature Indicating and Recording Circuits; Telemetry, Analog, Operations Recorder, etc.
uc - Code Call Circuits
v - Voltage (Potential) Transformer Secondaries and DC Voltage Leads
ut - Carrier or Pilot Wire Circuit
x - Excitation Circuits

e. Code identification notes.

(1) The list of letters in paragraph 15-4*d*(1) is used for separately mounted apparatus only. Instrument transformers and disconnecting switches are given individual designations only if they are mounted by themselves, as in an outdoor structure or in a similar indoor arrangement.

(2) Instrument transformers and disconnecting switches mounted on a circuit breaker or circuit breaker structure have the cable and conduit designations of the breaker. For example, bushing-type current transformers and potential devices mounted on oil circuit breaker XJ3 have cable and conduit designations such as "S3-a1-XJ3" and "S3-v1-XJ3"

(3) Cable terminal designations are used to designate major assemblies such as a switchgear assembly and not an individual breaker within the switchgear. Individual breaker designation is desirable, but including it in the terminal designation (first term of cable code) would complicate the system impairing its usefulness. Thus, instrument transformers, breakers, and disconnecting switches mounted in a switchgear or switchboard take the terminal designation of the switchgear or switchboard. For example, a breaker mounted in a 480-V switchboard has a cable and conduit designation of "SQ" for the first term and even though the breaker may have a number, this number is disregarded in the first term of the cable code. Where there are only a few breakers, the lack of a more positive identification is not objectionable.

(4) When a switchboard has a large number of breakers, considerable time may be consumed in locating the cable. To overcome this objection, the second term of the cable code is numbered to correspond with the breaker number. For example, CQ2-q8 and CQ2-q25 are 480-V power circuits connected to breaker No. 8 and No. 25, respectively, in 480-V cabinet No. 2. No difficulty is encountered because the number in the second term serves to differentiate one cable from another and doesn't indicate the total number of cables from a point.

(5) The order of terminal designation follows the order given in the code. For example, a cable between a lighting switchboard and a lighting cabinet is designated as "SR2-r4-CR5." The switchboard table precedes the load center table, the switchboard designation being the first term and the load center the last term. Other examples would be SJ-j2-G1 and CP-p1-K2. This order of designation is maintained for items of the same table; e.g., SC-a1-SP or A2-c1-G2.

(6) Because of the complicated code, the designation's primary application is in the powerhouse. The same designation may be used with a prefix to signify location at a different feature of the project. For example, DCR can represent a lighting cabinet in the dam.

(7) Similarly, FCQ represents a fish facility 480-V control center. This system is maintained at the powerhouse for terminal equipment, cables, and conduits servicing the fishway next to the powerhouse and also is maintained partially at the fishway. However, on portions of the fishway including collection channels, diffusion chambers, and the various gates, it is desirable to use designations employed in the structural and mechanical design and having name familiarity. Designations and locations of these elements of fish facilities are project-specific.

(8) Cable running from one part of the project to another should be clearly identified. For instance, the 4160-V cables originating at the powerhouse and used to supply power for the fishway, dam, and lock may have a designation SP - p1 to the first point of connection, SP - p1.1 between the first and second points of connection, and SP - p1.2, and so on, for the subsequent points.

(9) Powerhouse drawings showing the cable running to the fishway should indicate the cable number and give reference to the fishway drawing in which the other terminal of the cable is shown. Similarly, the fishway drawings should indicate the cable numbers for the cable in both directions and references given to both powerhouse and dam drawings.

(10) Wiring diagrams for a large switchboard or switchgear assembly are on several drawings, so considerable time is consumed in locating the proper drawing and the proper panel. To avoid this difficulty, each switchboard has its front panels numbered in order from left to right. The panel designation is the switchboard designation followed by the panel number, and the cable number then designates the panel at which it terminates. For example, on Generator Switchboard No. 1, the third panel from the left would be designated "S13" and a cable running from this panel has a designation such as, "S13-c1-TO."

(11) In duplex switchboards, a rear panel is designated by the letter "R" followed by a number corresponding to its front panel. For example, on Generator Switchboard No. 1, the third rear panel from the right

(facing the front of the rear panels) is designated “S1R3” and a cable running from this panel has a designation such as “S1R3-c1-TO.”

(12) Some vertical sections of a motor control center assembly may include two or more lighting panels, in one instance with the same voltage classification (e.g., CR-r and CA-r). The lighting panel designation is used in lieu of the vertical section number in these instances. A motor control center could include lighting panels of the following designations:

SU1 - - - CR11, CE11, CF11, CA11, CB11

SU2 - - - CR21, CE21, CF21, CA21, CB21

SU3 - - - CR31, CE31, CF31 CA31, CB31

SU4 - - - CR41, etc.

f. Lighting circuits. With lighting circuits, it is desirable to deviate from the general plan of providing a relationship between the conduit and its contained circuits. Branch circuits from lighting cabinets are numbered to comply with the power circuit guide. The numbering of branch conduits from lighting cabinets complies with the guide, except the conduit number bears no relationship to the numbers of the circuits running through it. The conduit number is initially determined by sequence numbering in a clockwise direction from the upper right-hand corner when facing the lighting cabinet and is not affected by circuits and conduits feeding the lighting cabinet. Where more than one row of knockouts is involved, the sequence of numbering is from front to back and clockwise.